

## LOW BAROMETER READINGS IN WEST INDIAN DISTURBANCES OF 1932 AND 1933

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The summer of 1933 was, even at the end of September, characterized by a record-breaking number of West Indian disturbances, and these storms produced five ships' barometer observations between 27.40 and 27.99 inches. Five other pressure readings on ships at sea were reported in the range from 28 to 28.50 inches, making 10 cases this year (up to September 30), in which ships have experienced and verified in mail reports to the Weather Bureau, such uncommonly low barometric minima in their encounters with West Indian hurricanes.

Pressures of 28.50 or lower in tropical disturbances characterize storms of severe hurricane intensity. The following table records all such observations so far in hand for the 3 months, July to September, inclusive, 1933.

Table of ships' barometer observations, 28.50 inches or lower, in West Indian hurricanes of July, August, and September 1933

Date	Name of vessel	Position		Lowest barometer
		Latitude N.	Longitude W.	
July 5, 1933	Am. S.S. Lena Luckenbach	25 32	90 40	28.50
Aug. 18, 1933	Nor. S.S. Tana	123 00	154 30	27.98
Aug. 30, 1933	Br. S.S. Jamaica Pioneer	22 10	72 30	27.47
Sept. 2, 1933	Am. S.S. Harvester	125 00	186 00	27.99
Sept. 11, 1933	Fr. S.S. Washington <sup>1</sup>	23 15	61 40	27.96
Sept. 15, 1933	Am. S.S. El Oceano <sup>2</sup>	134 00	174 30	28.24
Sept. 16, 1933	Am. S.S. Shenandoah <sup>3</sup>	36 35	75 00	28.43
Do	Am. S.S. Gulf of Mexico <sup>3</sup>	36 35	74 41	28.48
Sept. 17, 1933	Ger. S.S. Bremen <sup>3</sup>	39 54	69 16	28.50
Sept. 20, 1933	Am. S.S. Virginia	118 30	183 05	27.40

<sup>1</sup> Positions closely estimated.

<sup>2</sup> Uncorrected aneroid reading, but evidence indicates instrument in good order.

<sup>3</sup> Observations of Sept. 11-17, all obtained in same storm.

The 5 readings below 28 inches were obtained in 4 separate storms. Furthermore, the lowest reading in each of these storms was observed within 1 or 2 days after the time at which the disturbance became definitely located in our reports, and no lower readings thereafter have as yet come to light, although in all cases these storms appear to have increased in extent and destructive power as they passed onward to later stages of development.

This group of records therefore supports the view that tropical disturbances often, or perhaps commonly, arise as intense vortices of small diameter, which expand in area and decrease in intensity as they progress.

As bearing upon this question, it may be pointed out that the lowest of the readings, 27.40 inches (reported from the American liner *Virginia*), was observed under the following circumstances that clearly indicate a recently developed vortex of extraordinary sharpness. Meteorological conditions were somewhat disturbed in the Caribbean Sea for almost a week prior to September 20, when the *Virginia* encountered the storm described below, but no ship reported stormy weather until the 19th, when definite signs of development were observable in the region south and west of Jamaica. The following afternoon revealed the focus of activity as a small but intense hurricane near Swan Island.

The report of J. E. Handran and J. F. Wilson, observers on the *Virginia* (Capt. C. V. Richardson), is worthy of quotation at length and extracts are given below. The aneroid barometer used on the ship is subject to a cor-

rection of  $-0.05$  inch, which was applied to the readings before quotation in this report, which says:

At 5 p.m. (Sept. 20) it was blowing a moderate (NNE.) gale. At 6 p.m. the wind had further backed into the NE., force 8, with the barometer reading 29.95 inches. A speed of 17.5 knots was at this time cut down to 14 knots due to the heavy head swell which was being encountered.

At 6:55 p.m. the wind and sea had increased to such an extent that a further reduction in speed was necessary, to about 8 knots. Position  $18^{\circ}38' N.$ ,  $83^{\circ}07' W.$

Shortly before 8 p.m. a squall of great violence struck the ship and at 8 the ship was hove to, heading  $180^{\circ}$ , bringing the wind on the port quarter. Revolutions were adjusted to keep bare steerage-way. The aneroid barometer at this time, approximately 8 p.m., was reading 28.74 inches. Five minutes later it was down to 28.50 inches. The wind was now blowing in almost continuous squalls of great violence, with torrential rain. The noise from the wind was terrific, it being impossible to hear.

At 8:20 p.m. the wind suddenly ceased and looking directly overhead a few stars were visible over a small area. Men's ear drums were ringing, with the barometer standing at 27.40 inches during the calm center or "eye" of the hurricane. While in the calm area in a high confused sea the vessel was headed  $55^{\circ}$  true in anticipation of a change of wind. At 8:35 p.m. the wind struck in from the SSW. with slightly less force than before.

The wind continued to blow in squalls of hurricane violence from the SSW., with a rapidly rising barometer, when at 9 p.m. the glass stood at 28.60. Between 9 and 10 p.m. the wind moderated sufficiently to allow of bringing the vessel back to the course ( $150^{\circ}$ ) with the wind about 4 points on the starboard bow. Barometer reading 29.20. From 10 p.m. the speed was increased to full at 11 p.m., at which time the barometer stood at 29.40; wind S., force 9. At midnight the wind had further decreased to force 8; barometer, 29.66.

Careful examination of the information given in this report shows that the diameter of the ring of pressure below 29.50 inches could not have been much more than 50 miles when the ship crossed the storm area. The inner area of extreme violence, encompassing pressures below 28.50 inches, passed while the vessel was hove to. That part of the vortex, therefore, may be estimated as not over 10 to 12 miles in diameter, because 1 hour's progression carried that section of the hurricane past the drifting ship, and the evidence at hand indicates that the storm movement between the evening of the 20th and the morning of the 21st was not rapid.

Increase in the hurricane area during the few hours covered by these observations is indicated by the slower rate of rise than of fall in the barometer. This hardly could be attributed to a variation in the ship's movements relative to the storm for the route of the ship was about  $90^{\circ}$  to the storm track and the variations in sailing speed were similar in entering and leaving the hurricane. The later synoptic charts also carry the story of increase in size as this storm moved along its track westward to Tampico, where the hurricane struck with great violence on September 24 when the diameter of the 29.50 isobar was about 300 miles.

The fact that the center of this very small vortex had a clear spot "directly overhead", also indicates that at that time the disturbance was moving rather slowly, for there is much reason to think that with rapid movement the core of a tropical disturbance commonly is inclined in the direction of advance, with no clear sky visible in the region of lowest pressure. This point is not yet fully established; it is worthy of special notice and ships' observers are requested to supply more information on the character of the sky at the center of such disturbances when encountered.

The pressure (27.47 inches) observed on the British steamer *Jamaica Pioneer*, August 30, near Turks Island, ranks next lowest among the cases here reviewed. Examination of the detailed report in this instance also shows a very sharp vortex. The ship was only 7½ hours within the circle of pressures below 29.50 inches, and about an hour and 10 minutes while it was below 28.50 inches. The storm could not have been more than 2 days old at the time the *Jamaica Pioneer* crossed the center. This hurricane was moving quite rapidly at the time, and no clear eye was reported. Three days later the American steamer *Harvester* recorded 27.99 inches in this storm.

Readings below 28 inches in the other two storms, as reported by the Norwegian steamship *Tana* (Aug. 18), and the French ship *Washington* (Sept. 11), were also obtained at times when we must assume the cyclones to have been at a comparatively early stage of development. In neither of these storms can any center be definitely located or actual storm winds found in our reports more than 1 or 2 days prior to the date of the ship's encounter with the vortex.

The table carries five records taken at different times in the same storm, between September 11 and 17. It is of interest to note that these readings together constitute a consistent progression of dates, positions, and pressure values; this must be because the central pressure slowly increased as the storm progressed along its track.

In this connection, and bearing upon the question of the pressure distribution in tropical disturbances, reference is made to a report (not previously published in the REVIEW) obtained from the British steamer *Phemius*, which was involved for 4 days in intense hurricane conditions in the western Caribbean Sea in early November 1932. The meteorological log of this ship's experience, as given in detail in the British MARINE OBSERVER for October 1933 (vol. 8, pp. 123-125), indicates a hurricane

of full maturity and of what appears to be unusual complexity of structure.

The lowest pressure observed on the *Phemius*, 27.01 inches (914.6 mb.), was reached on the 5th near 14° N. 79° W., and within a few hours after the vessel entered the hurricane area. This is one of the lowest barometer readings ever observed at sea level, and the lowest fully authenticated reading in the West Indian region so far as can be ascertained at this writing.

The fall in barometer as this vortex approached was very rapid, and was attended by hurricane winds so intense that superstructures on shipboard were badly damaged, and the ship's funnel actually torn out and blown overboard. The vessel was from that time disabled, and wallowed in the seas throughout the remainder of the storm.

The barometer did not rise with equal promptitude, however, and the height that prevailed a few hours before the vessel's encounter with this terrific vortex was not again reached for 4 days. Instead, there was a partial rise, followed by several marked decreases, to 28 inches on the third day and 27.92 on the fourth, as if there might have been either a family of subvortices or vacillation in the movement of the primary storm center. During those 4 days the ship was involved in continuous storm conditions of great severity, with the barometer for 3 days never rising above 28.50 inches.

This hurricane was the same that on November 9, 1932, advanced northward across Cuba and devastated the city of Santa Cruz del Sur, with the loss of several thousand lives. Its meteorological history in the western Caribbean has not been fully worked out, but the record of the *Phemius* very clearly shows an extent and complexity of structure that throws this case into great contrast with the simpler vortices reported in the ship's observations of 1933.

## TROPICAL DISTURBANCES OF SEPTEMBER 1933

By C. L. MITCHELL

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*Tropical disturbance of August 31-September 7.*—This disturbance was central about 150 miles north of Puerto Rico the morning of the 1st. It evidently was attended by winds of hurricane force nearer its center at this time, inasmuch as the S.S. *Gulf Wing* reported a barometer reading of 28.98 inches and a wind velocity of 80 miles per hour about 150 miles east of Turks Island the evening of the 1st. The center passed some distance north of Turks Island during the night of the 1st-2d and over Harbour Island, about 2 miles northwest of the island of Eleuthera, Bahamas, the morning of the 3d. There was a calm of 30 minutes at this place. Previously the wind had reached an estimated velocity of 140 miles per hour. At 4 p.m. of the 3d, northwest storm warnings were ordered displayed at Miami, hurricane warnings north of Miami to Melbourne, Fla., and northeast storm warnings north of Melbourne to Jacksonville. At 10 p.m. storm warnings were displayed on the west Florida coast north of Key West to Cedar Keys.

The storm center apparently passed directly over Jupiter Inlet, Fla., where there was a lull of 40 minutes beginning near midnight of the 3d. The lowest barometer reading at Jupiter was 27.98 inches and the estimated maximum wind velocity 125 miles per hour. At West Palm Beach the lowest barometer reading was 28.77 inches with a maximum wind velocity close to 80 miles per hour. According to the official in charge at Miami,

the only evidence of damage at West Palm Beach was the effects of high winds upon trees and shrubbery. However, a number of plate glass windows were broken and the damage in this respect would have been much greater except for the extensive protective measures taken. Between West Palm Beach and Jupiter, and extending northward to Fort Pierce, there was serious damage to electrical transmission lines and to telephone and telegraph wires, with many poles broken off or blown over. At Stuart there was serious damage from both wind and water. The most extensive damage in the entire storm area was at Olympia Beach, north of Jupiter Inlet, where there was widespread destruction of trees and shrubbery and serious damage to houses. The greatest loss was to the citrus crop in the Indian River section from Jupiter to Fort Pierce. In the vicinity of Stuart there are several groves that sustained a 100 percent loss of fruit and the uprooting of many trees. The estimated loss of citrus fruit for the State is 16 percent, or 4,000,000 boxes.

This storm recurved to the north during the afternoon of the 4th when its center was near the coast north of Tampa. Moving very slowly northward with diminishing intensity during the next 2 days it dissipated over Georgia on the 7th.

*Tropical disturbance of September 10-21.*—Although conditions were disturbed over and east of the Leeward Islands from the 7th to the 9th, it was not until the 10th